

The Role of Simulation in Repository Design and Analysis

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Disclaimer

Assume the Yucca Mountain Repository “as-is”:

- o **63,000 metric tonnes of commercial spent nuclear fuel**
- o **7,000 tonnes of DOE waste**





Assumed Future Regime

O Assume a new reactor regime with recycle:

- LWRs
- LWR fuel reprocessing
- Fast reactors (that burn actinides)
- Fast reactor fuel reprocessing
- Waste streams:
 - o Actinides recycled (not a waste)
 - o HLW from reprocessing
 - o Uranium in purified form
 - o Cs & Sr possibly separated out

Opportunity with the Assumed Future Regime



The new regime significantly changes the options available for optimizing waste management.



Assumed Future Repository

[for the purposes of discussion only]

ASSUME: The new repository site is exactly like Yucca Mountain.

Why?

Because no site in the U.S. has been as well characterized.

3 Questions are Posed in this Talk



- 1) **What do we need to know (*in addition to what is already known*) to dispose of the new waste streams with adequate safety and security?**
[needed for regulatory approval]
[needed for public policy – especially vis-à-vis security]

- 2) **What should we want to know to achieve substantial efficiencies and optimization with the repository?**
[this is a true "systems problem"]

- 3) **How best do we attain the above?**



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WHAT

WHAT

HOW



3 Questions are Posed in this Talk

QUESTION #1

What do we need to know (*in addition to what is already known*) to dispose of the new waste streams with adequate safety and security?

[see *later slides*]

3 Questions are Posed in this Talk



QUESTION #2:

What should we want to know to achieve substantial efficiencies and optimization with the repository? [a true "systems problem"]

Optimize among the following:

- dose impact to the public
- life-cycle cost
- capital cost
- dispose of more waste in the same "real estate"
- optimal use of the "real estate"
- national and international security
- transportation

LOTS OF “KNOBS” TO TWIDDLE WITH

3 Questions are Posed in this Talk



QUESTION #3:

How best do we attain the above?

- O How do we optimize cost and schedule?
- O How do we reduce national security risks to acceptable levels?
- O How do we maximize our confidence in our analysis/understanding?

ONE MAJOR CHALLENGE:

How do we manage the transition from today's LWR once-through system to the mixed LWR & fast-reactor & recycle system of the future?



CONSTRAINTS on the REPOSITORY DESIGN

- O Regulatory compliance
- O ANALYZABILITY must be a DESIGN CRITERION.
- O The SAFETY CASE must be TRANSPARENT.
- O Design constraints:
 - Criticality
 - Severe radioactive environment
 - Severe thermal temperatures
- O Must be monitorable --- for “performance confirmation”



5 Families of Nuclear Waste Streams

- O Strontium-90 and Cesium-137
- O Longer-lived fission products
- O Particularly important long-lived fission products (Tc-99, I-129)
- O Separated very pure uranium
- O Plutonium
- O Other (minor) actinides



“Grand” or “Highest Level” Options

- 1) **Which waste streams go where** is a major optimization issue.
- 2) The above issue affects how the rest of the Nuclear Power scheme is deployed. It affects:
 - O performance spec's for LWR fuel reprocessing
 - O performance spec's for fast-reactor reprocessing
 - O performance spec's for the fast reactors themselves
 - O the transportation scheme
- 3) The optimization needs to account for national & international security



**Treating the repository "real estate" as a scarce resource
with a specified monetary value allows for
rational optimization.**



- O Optimize waste forms --- "source term" vs. cost
 - Can Tc, I, Np be sequestered at reasonable cost?
- O Waste package materials
 - Novel new materials
 - Understanding corrosion
 - Understanding strength under drift-collapse/rockfall
 - Behavior under "backfill"
 - W.P. failure mechanisms
- O Modeling of the seismic scenarios
- O Modeling of the volcanic-intrusion scenarios



Grand Challenges, Repository Design (continued)

- O **Drift engineering**
 - Drift size and spacing
 - Backfill
 - Collapse
- O **UZ (Unsaturated Zone)**
 - Flow above the drifts
 - Interaction of flow with the drifts
 - Transport below the drifts
- O **SZ (Saturated Zone) Flow and Transport**
- O **UZ and SZ behavior**
 - "normal" present-day (interglacial) conditions
 - glacial conditions
 - "super-glacial" conditions



- O Minimize remote handling complexity
- O Seismic design --- equipment
- O Minimize multiple steps and transfers
- O Design facilities used for "emplacement preparation"
 - the "last weld" problem
 - design criterion --- inspectability
- O Minimize dry-storage durations and operations
- O Integrate transportation with surface-facility operations & with emplacement operations



(an iterative process)

- O Optimization of the repository (*given the complexity in the above issues and constraints*) is itself a major problem.
- O Once "optimized" based on specified waste-streams, there must be feedback to the larger nuclear-reactor-&-reprocessing system, for higher-level optimization.
- O The optimization will be time-dependent, changing over the years.



Grand Challenge – Simulation (continued)

The optimization will be time-dependent.

- **Technological developments will affect it.**
- **Cost development in competing areas will affect it.**
- **The financial situation will affect it (long-term interest rates, availability of capital, etc.)**
- **Societal expectations will affect it (risk perceptions, environmental emissions limits, intergenerational equity, regional equity, societal stability).**



- O The simulation must have both technological and financial/economic elements.

[Question: Which elements must be “embedded,” and which ones can be “exogenous”?]

- O The simulation must be both at the higher level of the major "building blocks" of the nuclear power energy system, and at the detailed level of the major "pieces" of the repository system.
- O The iteration process must be maintained for a very long time.